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WIND VARIABILITY AND ITS EFFECT ON ROCKET IMPACT PREDICTION

PREPARED BY

MISSILE METEOROLOGY DIVISION

U. S. ARMY
ELECTRONICS RESEARCH AND DEVELOPMENT ACTIVITY
WHITE SANDS MISSILE RANGE
NEW MEXICO

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ABSTRACT

The variability of wind from 200 to 2000 feet above the surface at White Sands Missile Range was studied. Wind variability as a function of time (3.5, 4.0, 8.0, 10.0, and 11.5 minutes) is presented. Data for the study were obtained from double-theodolite pilot-balloon observations.

The absolute mean and the standard deviation of the difference in wind velocity for 100-foot intervals from 200 to 2000 feet indicate the magnitude of the change that can be expected in a given time increment for a given height level. The effect of this variability on the computed impact point of an Aerobee rocket is discussed.

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TABLES

INTRODUCTION

One of the basic problems confronting the meteorologist who is predicting impact of an unguided rocket* is the extreme variability of the wind in the first 2000 feet above the surface. To complicate matters, according to J. V. Lewis [1] and H. A. Daw [2], 70 per cent and 65 per cent, respectively, of the total wind weighting factors are in this region. Because of this heavy weighting effect in the lower layer**, a slight variation in the wind profile can cause a large change in the computed impact point of a rocket.

The purpose of this report is to show the extent of wind variation from 200 to 2000 feet expressed in terms of standard deviation and the effect of this variation on the computed impact point of an Aerobee rocket.

The authors realize that since the wind variability in this study is computed from double-theodolite pilot-balloon observations (pibals), there is a spatial and time variability error involved as it is unlikely that balloons will have the same ascent rate or that a given balloon will be at exactly the same location as any previous one. Also, it is realized that a certain amount of instrumental and observational error exists which is not considered here.

DATA COLLECTION

DESCRIPTION OF SITE

Pilot-balloon observations were made approximately 10 miles east of the Organ Mountains which are oriented in a north-south line. The average height of the mountains is approximately 8000 feet above sea level or 4000 feet above White Sands Missile Range. The surface area at the observation site for a radius of several miles is characterized by small brush-topped dunes averaging 6 to 10 feet in height.

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* Fin-stabilized rockets fired approximately in the vertical.

** Layer between the surface and 2000 feet.

OBSERVATIONAL PROCEDURE

The double-theodolite system [3] was utilized for collecting the raw data. The following criteria were used:

1. Baseline - 1000 feet.

2. Orientation of baseline - north-south line.

3. Balloon used - 30 gram.

4. Sampling interval - 20 seconds.

5. Total time of observation - 180 seconds.

6. Maximum height in each observation - approximately 2000 feet.

The observations were made at irregular intervals during a period of two years, i.e., generally three pibals were taken in one day but several days could elapse without any observations. A total of 276 observations yielded three sets of paired pibals. Each set contained 92 pairs of observations. The time separation between the observations that formed a pair for the three sets was 3.5, 8.0, or 11.5 minutes. Another 78 observations yielded a set of 39 pairs with a time separation of ten minutes between observations

In addition to the above data, 15 observations were made utilizing the Double-Theodolite Wind Velocity Computer [4]. The observations were made at consecutive time increments of 4 minutes beginning at 1410 MST and ending at 1510 MST. These data yielded 14 paired observations with a 4-minute separation.

DATA PROCESSING TECHNIQUES

The calculation procedure was divided into four parts:

1. The wind velocity was computed from the raw double-theodolite data by the constant time interval (40 seconds) method as described by Middleton et al [5].

2. Wind velocities at 100-foot intervals were obtained by parabolic interpolation between computed wind values as follows:

> A given segment of the wind profile between three consecutive wind values can be expressed as a parabola. Consider three consecutive points (Z_n, h_n), (Z_{n+1}, h_{n+1}), (Z_{n+2}, h_{n+2}) where h represents height

and Z the wind components under consideration. The general form for a parabola which expresses $Z = F(h)$ is

$$Z = ah^2 + bh + c \qquad (1)$$

where a, b, c are coefficients to be determined. Using the known values of Z and h, three simultaneous equations in a, b, and c are obtained,

$$Z_n = ah_n^2 + bh_n + c$$

$$Z_{n+1} = ah_{n+1}^2 + bh_{n+1} + c \qquad (2)$$

$$Z_{n+2} = ah_{n+2}^2 + bh_{n+2} + c.$$

The equations can be solved for a, b, and c. The wind components for 100-foot intervals are then obtained by evaluating (1) where Z is a variable representing the wind components.

3. Differences in wind velocity of the two observations which form a pair at the 100-foot intervals were determined.

4. The mean and standard deviation of the differences were calculated.

WIND VARIABILITY WITH TIME

Using the method presented, i.e., parabolic interpolation, the differences in wind velocity between the observations that formed a pair were tabulated for given height levels. The mean and standard deviation were calculated from these differences.

The absolute mean and standard deviation for the 39-pair set are shown in Table I. Unfortunately, data for this set yielded a height of only 1000 feet. The large dispersion of wind velocities as evidenced by examining the mean value and the standard deviation (Figures 1 and 2) indicates the degree of variability present.

To compare the results, wind variability was determined using the method outlined by Singer [6] for the 39-pair set only. The first quartile (Q_1), median (Q_2), and the third quartile (Q_3) of the differences of wind direction and wind speed are presented in Figure 3. The dispersion of the quartile distribution, i.e., Q_3-Q_1, are comparable to

TABLE I

Means, Standard Deviations and Variance of the Absolute Differences of Wind Speed and Wind Direction for 100-foot Intervals for a Ten-Minute Increment.

	WIND SPEED DIFFERENCES			WIND DIRECTION DIFFERENCES		
Height (Feet)	Mean (MPH)	S	S^2	Mean (Degrees)	S	S^2
200	2.4	2.2	4.98	30.3	30.4	922.00
300	2.2	2.4	5.88	27.8	30.4	924.03
400	2.1	2.3	5.34	20.7	17.5	306.71
500	2.3	2.0	4.15	19.9	26.4	698.77
600	2.6	2.3	5.20	20.9	21.4	456.85
700	3.2	2.6	6.75	19.2	30.6	934.76
800	3.0	2.5	6.49	21.2	32.8	1075.17
900	3.6	2.8	8.04	21.1	28.5	812.35
1000	3.6	2.7	7.47	20.6	23.6	555.84

Note: Data collected during 1959 at White Sands Missile Range.

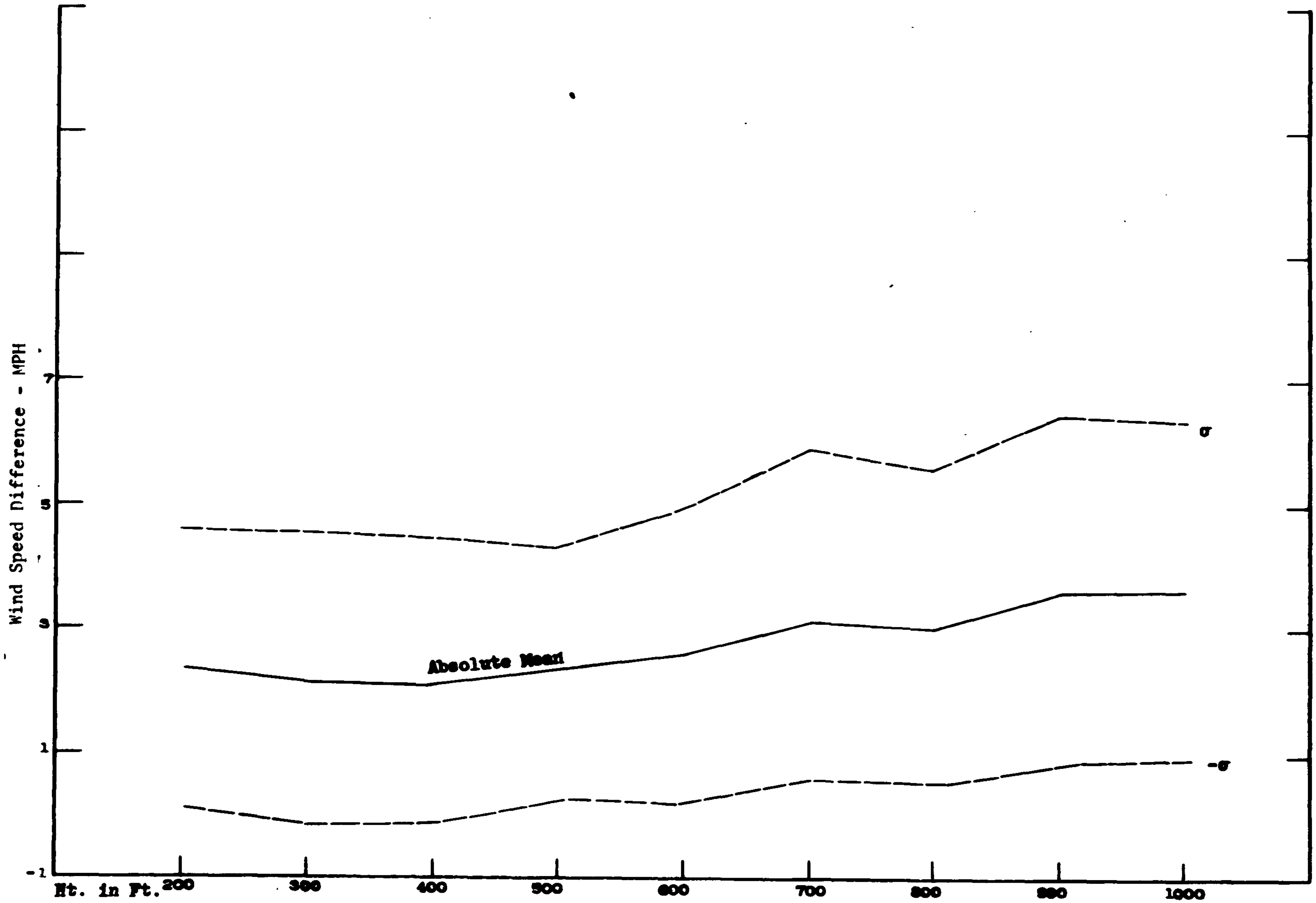


Figure 1. Wind Speed Standard Deviation About the Absolute Mean for 39 Pairs of Data

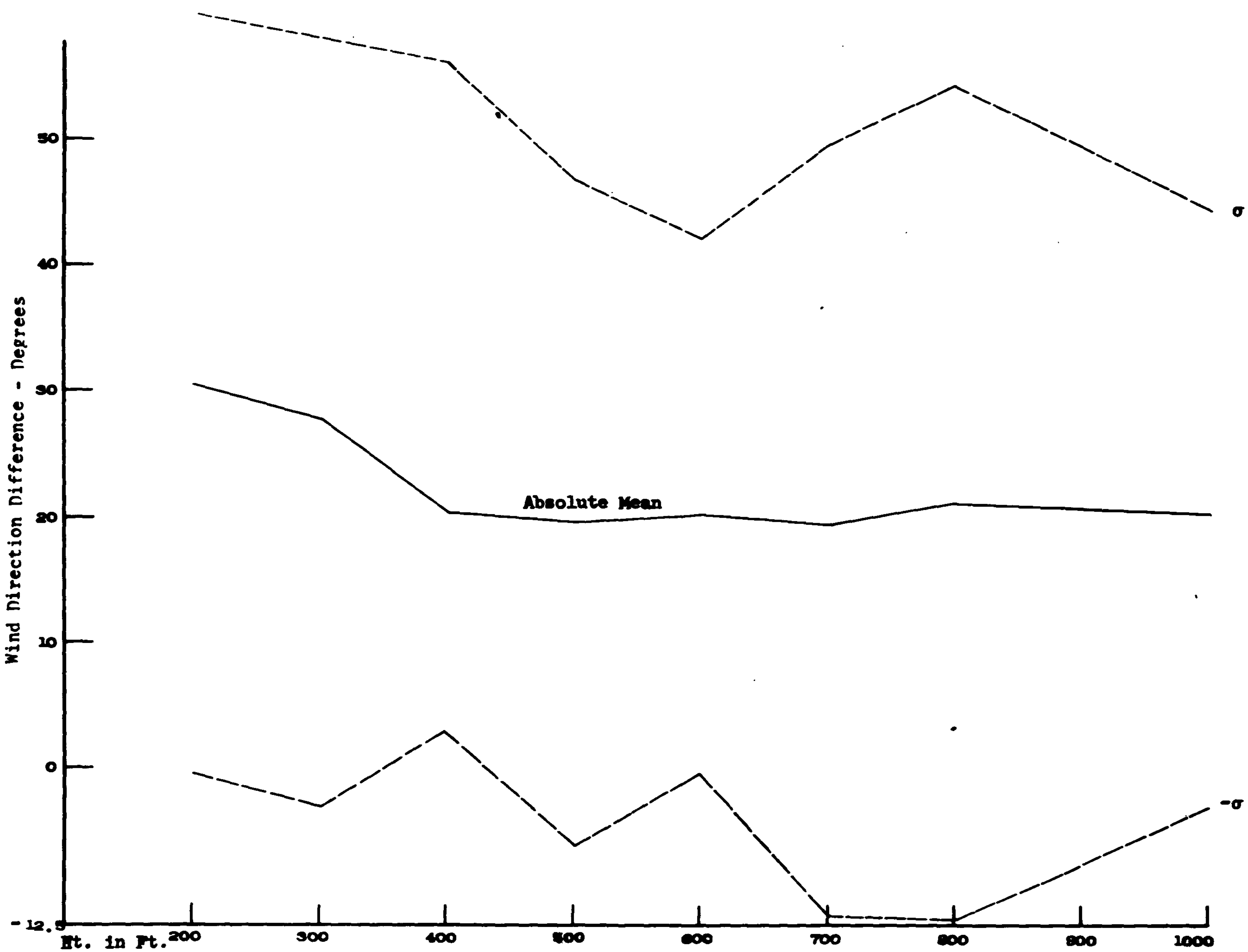


Figure 2. Wind Direction Standard Deviation About the Absolute Mean for 39 Pairs of Data

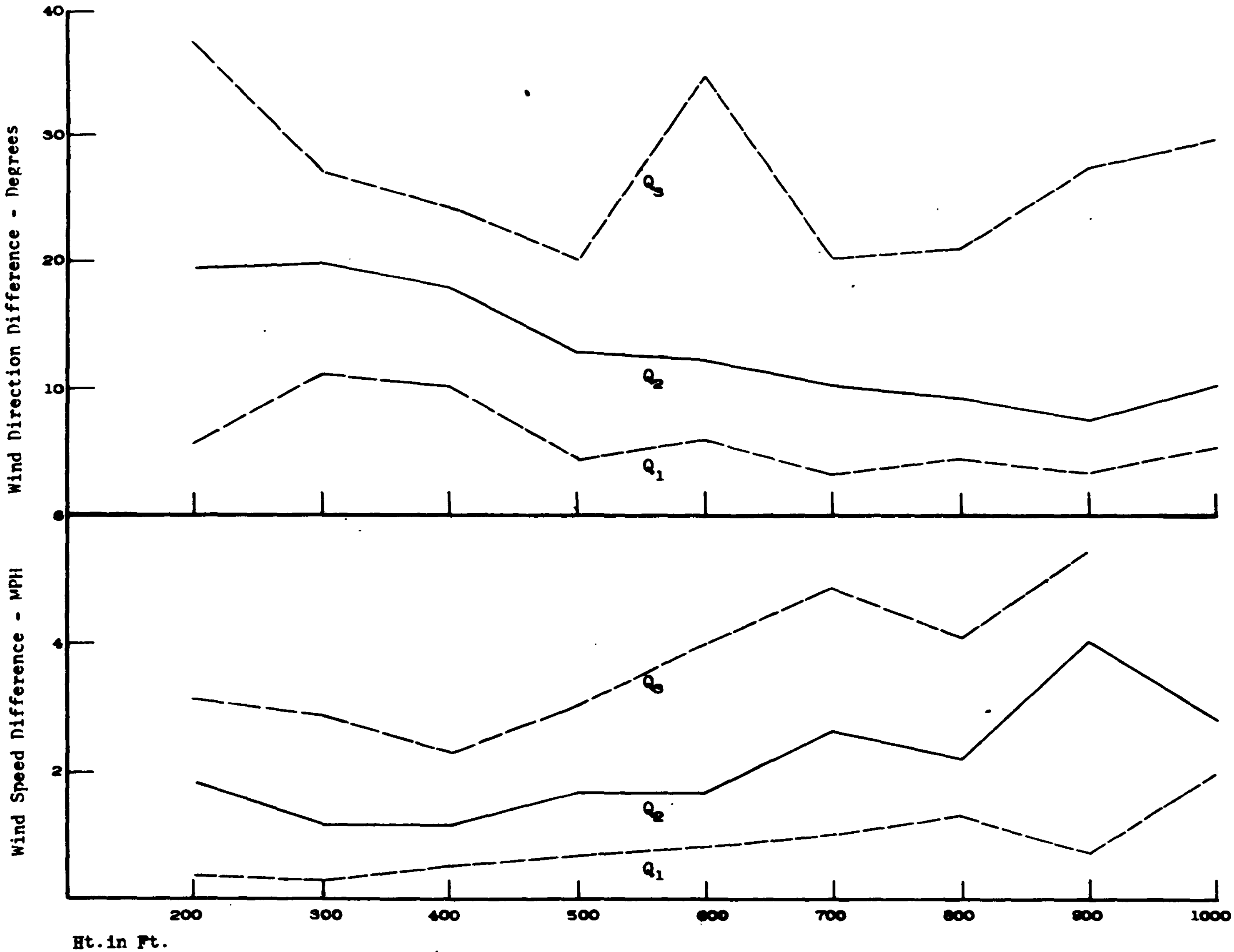


Figure 3. Quartiles for Wind Speed and Wind Direction Differences.

the values of the standard deviation shown in Table I.

The results of the 92-pair set are shown in Tables II to X. The standard deviations in the three time sets are taken about the algebraic mean. The absolute mean is included to show the average change that can occur for a given time increment. Extreme changes for each time increment are also included.

The results of the 14-pair set are shown in Table XI. Since the observations were taken during an hour of maximum turbulence (1410-1510 MST) it is not surprising to note the large dispersion indicated by the standard deviation. If we compare these figures with those of the 92-pair set for the 3.5-minute interval we find that the dispersion for the 14-pair set is almost twice that of the 92-pair set.

VARIABILITY EFFECTS ON IMPACT PREDICTION

Thirty-five Aerobee-150 rockets were fired during the International Geophysical Year (IGY) at Fort Churchill, Canada. These firings were analyzed to determine the reliability of the ballistic models in use and the accuracy of the impact prediction when compared to the actual impact point of the rocket [7]. It was found that 75 per cent of all actual rocket impacts occurred within a circle of a 25-mile radius whose center was the predicted impact point under conditions comparable to those which prevailed for the IGY firings. It was concluded that an improvement in the ballistic model used to compute the theoretical trajectory would improve the accuracy of impact prediction.

During 1960, an evaluation of the predicted impact of an Aerobee rocket versus actual impact for thirteen firings at White Sands Missile Range showed that 65 per cent of the actual impacts were within a 15-mile radius of the predicted impact. This increase in prediction accuracy can be attributed to four factors:

1. Increase in accuracy in measuring the wind, i.e., change from a single-theodolite system as used at Fort Churchill to a double-theodolite system.

2. Change in the ballistic model, i.e., from the Lewis theory to the Daw theory.

3. Lighter winds that are found near the surface at White Sands Missile Range as compared to the winds during rocket firings at Fort Churchill, Canada.

TABLE II

Means and Standard Deviation of the Differences of Wind Direction for 100-Foot Intervals for a 3.5-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference (Degrees)	Absolute Mean $\|\bar{X}\|$ (Degrees)	Algebraic Mean $\bar{X}$ (Degrees)	S_x
200	27	147	29.7	-1.8	47
300	70	143	25.8	-3.1	38
400	89	168	25.4	2.9	39
500	93	155	24.3	1.2	38
600	93	162	25.7	-5.1	39
700	92	178	25.6	-6.5	38
800	90	167	23.7	-5.3	38
900	88	161	22.9	-4.2	35
1000	81	161	27.0	-4.3	40
1100	77	129	27.8	3.0	40
1200	68	106	24.8	0.7	35
1300	57	128	25.1	2.4	38
1400	54	169	28.8	6.3	44
1500	49	153	25.5	5.7	42
1600	44	170	23.2	2.6	41
1700	35	84	16.8	4.9	26
1800	31	120	15.4	6.3	27
1900	26	105	17.9	7.0	29
2000	21	142	21.6	11.2	37

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE III

Means and Standard Deviation of the Differences of Wind Speed for 100-Foot Intervals for a 3.5-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference (MPH)	Absolute Mean $\|\bar{X}\|$ (MPH)	Algebraic Mean $\bar{X}$ (MPH)	S_x
200	27	6.1	2.0	-0.5	2.5
300	70	10.8	2.0	-1.0	2.7
400	89	12.5	2.4	-0.2	3.3
500	93	11.0	2.6	-0.3	3.3
600	93	13.7	2.4	-0.2	3.2
700	92	14.7	2.5	0.1	3.4
800	90	12.1	2.5	-0.2	3.4
900	88	14.6	2.7	-0.4	3.8
1000	83	14.5	3.0	-0.3	4.3
1100	77	11.3	2.8	-0.1	3.9
1200	68	11.3	2.7	0.1	3.7
1300	57	12.3	2.8	0.8	4.0
1400	54	12.3	2.6	0.7	3.8
1500	49	11.5	2.5	0.6	3.9
1600	44	10.6	2.7	0.3	3.7
1700	35	10.4	2.7	0.1	3.4
1800	31	9.1	2.5	0.1	3.1
1900	26	8.2	2.7	-0.1	3.6
2000	21	8.1	3.1	-0.7	3.9

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE IV

Means and Standard Deviation of Wind Component Differences ($\bar{y}$ = North-South, $\bar{x}$ = East-West) for a 3.5-Minute Time Interval (N = Number of Samples).

Height (Feet)	N	Absolute and Algebraic Means of the Differences of Wind Components-MPH				$S_{\bar{y}}$	$S_{\bar{x}}$
		$\lvert\bar{y}\rvert$	$\bar{y}$	$\lvert\bar{x}\rvert$	$\bar{x}$		
200	27	2.3	0.2	2.1	-1.0	2.9	2.7
300	70	2.4	0.1	2.3	0.3	3.4	3.5
400	89	2.5	-0.2	2.4	0.5	3.6	3.6
500	93	2.4	0.1	2.6	0.4	3.2	3.3
600	93	2.5	0.2	2.6	0.1	3.4	3.3
700	92	2.6	-0.3	2.3	0.2	3.7	3.0
800	90	2.7	-0.2	2.3	0.2	3.6	3.0
900	88	3.0	0.0	2.3	0.3	4.0	3.0
1000	81	3.3	0.1	2.5	0.3	4.5	3.2
1100	77	3.3	0.2	2.5	0.2	4.2	3.2
1200	68	2.9	0.4	2.5	0.1	3.8	3.3
1300	57	2.7	0.5	2.7	0.3	3.7	3.5
1400	54	2.5	0.5	2.6	0.5	3.6	3.5
1500	49	2.5	0.6	2.6	0.8	3.5	3.4
1600	44	2.2	0.5	2.7	0.7	3.0	3.4
1700	35	2.1	0.3	2.4	-0.1	2.6	3.1
1800	31	2.1	0.4	2.0	0.1	2.7	2.8
1900	26	2.6	-0.2	2.2	0.6	3.4	3.1
2000	21	2.7	-0.2	2.6	1.1	3.6	3.3

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE V

Means and Standard Deviation of the Differences of Wind Direction for 100-Foot Intervals for an Eight-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference (Degrees)	Absolute Mean $\lvert\bar{X}\rvert$ (Degrees)	Algebraic Mean $\bar{X}$ (Degrees)	S_x
200	34	132	34.3	-3.7	47
300	76	166	34.9	4.5	47
400	89	175	37.1	6.0	53
500	92	167	35.3	-1.7	52
600	92	161	37.9	2.7	56
700	91	155	35.2	10.3	50
800	88	169	29.6	7.9	44
900	85	173	28.1	7.2	41
1000	80	169	30.5	1.9	44
1100	72	142	28.2	4.3	42
1200	63	167	31.3	4.9	47
1300	53	166	34.1	-4.0	51
1400	47	174	34.8	-0.5	54
1500	43	163	30.9	0.2	49
1600	38	161	30.1	0.6	50
1700	30	148	28.8	-2.5	44
1800	27	172	30.1	-3.7	50
1900	22	175	34.4	8.4	59
2000	19	158	30.8	-6.1	55

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE VI

Means and Standard Deviation of the Difference of Wind Speed for 100-Foot Intervals for an Eight-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference MPH	Absolute Mean $\lvert \bar{X} \rvert$ MPH	Algebraic Mean $\bar{X}$ MPH	S_x
200	34	7.7	2.6	-0.2	3.5
300	76	9.1	2.9	0.2	3.6
400	89	11.7	3.0	0.5	4.1
500	92	12.3	3.2	0.6	4.2
600	92	11.3	3.1	0.4	3.8
700	91	12.5	3.2	-0.2	4.2
800	88	19.5	3.3	-0.1	4.6
900	85	15.2	3.2	-0.1	4.5
1000	80	15.9	3.3	0.0	4.5
1100	72	15.5	3.2	0.0	4.2
1200	63	13.7	2.4	0.1	3.4
1300	53	11.4	2.6	-0.2	3.5
1400	47	10.2	2.6	-0.3	3.5
1500	43	9.4	2.4	0.0	3.3
1600	38	10.1	2.5	0.3	3.5
1700	30	10.6	2.9	0.1	3.9
1800	27	10.7	2.9	-0.2	3.8
1900	22	10.5	3.2	-0.2	4.1
2000	19	9.4	3.3	0.6	4.1

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE VII

Mean and Standard Deviation of Wind Component Differences (y = North-South, x = East-West) for an Eight-Minute Time Interval (N = Number of Samples).

Height (Feet)	N	Absolute and Algebraic Means of the Differences of Wind Components-MPH				$S_{\bar{y}}$	$S_{\bar{x}}$
		$\lvert\bar{y}\rvert$	$\bar{y}$	$\lvert\bar{x}\rvert$	$\bar{x}$		
200	34	2.3	-0.2	2.9	0.7	3.2	3.5
300	76	3.2	0.3	3.2	-0.2	4.4	4.3
400	89	3.4	0.0	3.1	-0.5	4.6	4.4
500	92	3.3	-0.1	2.9	-0.2	4.4	3.8
600	92	3.2	-0.2	3.1	0.1	4.2	4.3
700	91	3.4	0.2	3.1	0.2	4.5	4.2
800	88	3.5	0.2	3.0	0.4	4.9	4.0
900	85	3.5	0.0	3.0	0.3	4.8	4.1
1000	80	3.5	-0.3	3.2	0.3	4.7	4.3
1100	72	3.2	-0.2	3.2	0.1	4.3	4.1
1200	63	3.0	-0.7	2.7	-0.2	4.1	3.6
1300	53	3.3	-0.6	2.5	-0.5	4.6	3.3
1400	47	3.3	-0.2	2.5	-1.0	4.7	3.3
1500	43	3.1	0.2	2.4	-1.5	4.3	3.0
1600	38	3.1	0.8	2.5	-1.1	4.1	3.3
1700	30	3.3	0.4	2.3	-0.3	4.5	3.6
1800	27	3.2	0.7	2.4	0.0	3.9	3.8
1900	22	3.3	0.6	2.7	-0.1	4.1	4.1
2000	19	3.1	0.5	2.7	-0.9	4.0	3.7

Note: Data collected during 1960 and 1961 at White Sands Missile Range

TABLE VIII

Means and Standard Deviation of the Differences of Wind Direction for 100-Foot Intervals for an 11.5-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference (Degrees)	Absolute Mean $\lvert\overline{X}\rvert$ (Degrees)	Algebraic Mean $\overline{X}$ (Degrees)	S_x
200	26	165	50.7	-8.2	73
300	73	160	43.3	-0.6	62
400	91	165	37.9	5.0	57
500	92	146	34.0	-0.4	52
600	92	149	35.9	-2.5	53
700	92	151	35.9	-3.9	51
800	90	158	33.0	-3.7	48
900	86	154	30.8	1.7	47
1000	82	149	30.5	1.2	47
1100	76	145	27.7	-1.9	44
1200	70	130	25.9	-1.2	37
1300	60	110	27.8	-2.7	39
1400	54	133	30.6	-4.4	44
1500	49	166	29.9	-8.1	46
1600	43	171	32.2	-1.0	50
1700	38	174	34.4	-1.3	55
1800	35	177	32.3	-4.5	53
1900	29	172	25.2	7.2	47
2000	26	164	24.2	-7.7	47

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE IX

Means and Standard Deviation of the Differences of Wind Speed for 100-Foot Intervals for an 11.5-Minute Time Increment (N = Number of Samples).

Height (Feet)	N	Maximum Difference (MPH)	Absolute Mean $\lvert\bar{X}\rvert$ (MPH)	Algebraic Mean $\bar{X}$ (MPH)	S_x
200	26	6.9	2.6	0.6	3.2
300	73	10.8	2.7	-0.6	3.7
400	91	11.0	2.8	0.3	3.7
500	92	10.2	2.8	0.2	3.6
600	92	12.2	2.7	0.1	3.7
700	92	14.1	3.1	-0.1	4.3
800	90	20.0	3.3	-0.3	4.8
900	86	22.8	3.2	-0.5	4.8
1000	82	20.5	3.4	-0.1	5.0
1100	76	13.9	3.2	0.0	4.4
1200	70	12.8	2.8	0.1	4.0
1300	60	9.8	3.0	0.1	4.0
1400	54	12.0	2.9	0.1	4.0
1500	49	15.9	2.9	0.2	4.1
1600	43	17.2	3.2	0.1	4.5
1700	38	12.1	3.3	-0.2	4.3
1800	35	8.3	3.2	-0.8	3.9
1900	29	9.4	2.8	-0.8	3.4
2000	26	10.2	2.5	-1.0	3.2

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE X

Mean and Standard Deviation of Wind Component Differences (y = North-South, x = East-West) for an 11.5 Minute Time Interval (N = Number of Samples).

Height (Feet)	N	Absolute and Algebraic Means of the Differences of Wind Components-MPH				$S_{\bar{y}}$	$S_{\bar{x}}$
		$\lvert\bar{y}\rvert$	$\bar{y}$	$\lvert\bar{x}\rvert$	$\bar{x}$		
200	26	2.6	-0.3	3.1	0.5	3.7	3.9
300	73	3.4	0.4	3.0	0.4	4.7	3.9
400	91	3.5	-0.2	2.8	0.1	4.7	3.8
500	92	3.3	0.0	2.9	0.1	4.4	3.9
600	92	3.2	0.0	3.1	0.2	4.2	4.2
700	92	3.5	0.0	3.2	0.4	4.7	4.3
800	90	3.6	-0.1	3.3	0.5	4.8	4.4
900	86	3.4	-0.2	3.3	0.5	4.7	4.4
1000	82	3.3	-0.5	3.6	0.5	4.7	4.7
1100	76	3.0	-0.1	3.2	0.3	4.0	4.2
1200	70	2.9	0.0	2.9	-0.1	3.9	3.7
1300	60	3.2	0.2	2.6	-0.1	4.1	3.4
1400	54	3.1	0.3	2.7	-0.2	4.1	3.6
1500	49	3.0	0.7	2.7	-0.3	4.2	3.5
1600	43	3.5	1.2	2.8	-0.2	4.8	3.6
1700	38	3.8	1.2	2.6	-0.2	5.2	3.4
1800	35	3.2	1.2	2.6	0.1	4.0	3.3
1900	29	2.5	0.7	2.9	0.0	3.3	3.6
2000	26	2.1	0.6	2.9	0.3	2.7	3.7

Note: Data collected during 1960 and 1961 at White Sands Missile Range.

TABLE XI

Means and Standard Deviations of the Differences in 100-Foot Intervals for a Four-Minute Time Increment. (S_y = North-South Winds; S_x = East-West Winds; $\bar{X}$ = Mean; $|\bar{X}_y|$ = Absolute Mean of North-South Winds; $|\bar{X}_x|$ = Absolute Means of East to West Winds.)

Height (Feet)	$\lvert\bar{X}_y\rvert$	$\bar{X}_y$	$\lvert\bar{X}_x\rvert$	$\bar{X}_x$	S_y	S_x
200	4.3	0.46	4.6	-0.79	6.2	5.8
300	3.33	0.44	5.0	-0.84	5.3	6.2
400	4.1	0.30	4.9	-0.14	5.2	6.2
500	5.4	0.38	5.2	-0.19	8.2	7.0
600	4.8	0.32	4.7	-0.10	7.4	6.5
700	3.8	0.10	5.1	-0.23	6.1	7.4
800	3.4	0.26	5.3	0.05	5.5	7.7
900	4.1	0.47	6.0	0.83	6.3	8.7
1000	4.7	-0.11	6.9	-0.11	7.3	9.2
1100	5.2	-0.09	6.4	-0.06	8.1	8.7
1200	6.1	-0.07	5.9	0.29	9.2	7.7
1300	4.5	-0.16	5.2	0.39	6.9	7.9
1400	5.8	-0.19	5.1	0.19	8.5	7.7
1500	6.9	-0.34	6.2	0.21	10.5	8.5
1600	6.8	-0.34	6.9	0.34	10.5	9.1
1700	6.3	-0.06	5.7	0.56	9.1	7.3
1800	5.1	1.07	5.4	0.93	8.3	8.2
1900	5.6	1.14	5.7	0.88	8.7	8.7
2000	5.7	1.00	6.3	0.79	9.0	9.9

Note: Data collected during an hour (1410-1510 MST) of maximum turbulence on 9 May 1962 at White Sands Missile Range.

4. Experience in impact predicting gained at Fort Churchill applied to firings at White Sands Missile Range.

Comparisons of predicted impact of an Aerobee rocket versus actual impact during 1961 and the first six months of 1962 showed no significant improvement in impact prediction over 1960. The value of the standard deviation as computed for the five sets of data was applied to the ballistic problem of the Aerobee rocket to determine the dispersion of the computed impact caused by wind variability alone. The results are shown in Table XII.

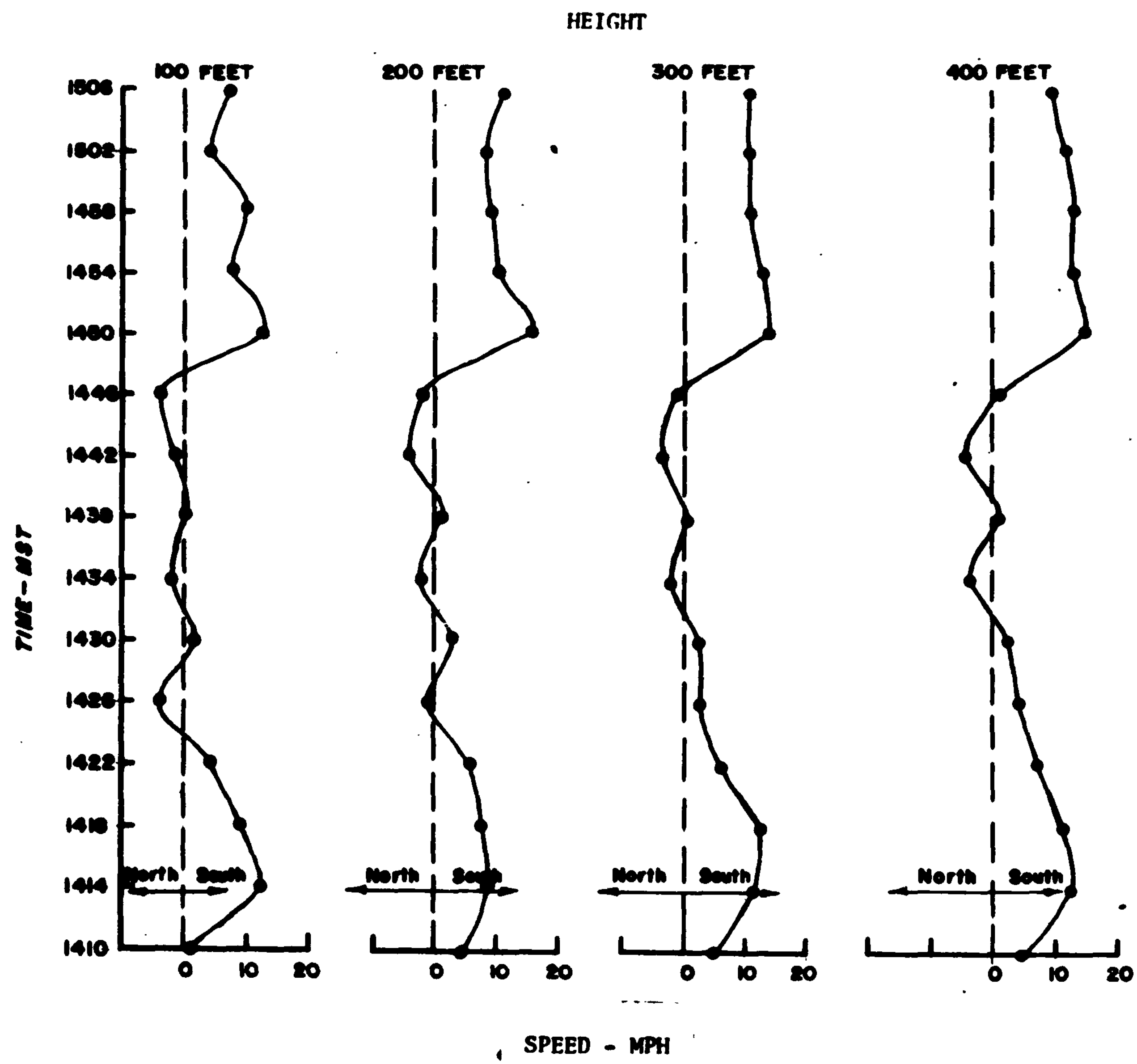
TABLE XII

Dispersion of Computed Impact of an Aerobee Rocket. Computations are Based on the Standard Deviation for the Different Time Increments.

TIME INCREMENT (MINUTES)	RANGE (MILES)	AZIMUTH CHANGE (DEGREES)
3.5	7.5	35
4.0	18.0	45
8.0	11.0	45
10.0*	5.0	30
11.5	11.0	45

*Standard deviation was computed about the absolute mean for the 10.0-minute set only.

The wind components for the 15 observations are plotted as a function of time for given height levels in Figures 4 to 9. The abrupt wind shift that occurred between 1446 and 1450 MST was applied to the ballistics of an Aerobee rocket. The difference in impact displacement between the two observations was over 50 miles (Table XIII).



N-S WIND COMPONENTS PER
UNIT TIME - (100-400 FEET)

FIGURE 4

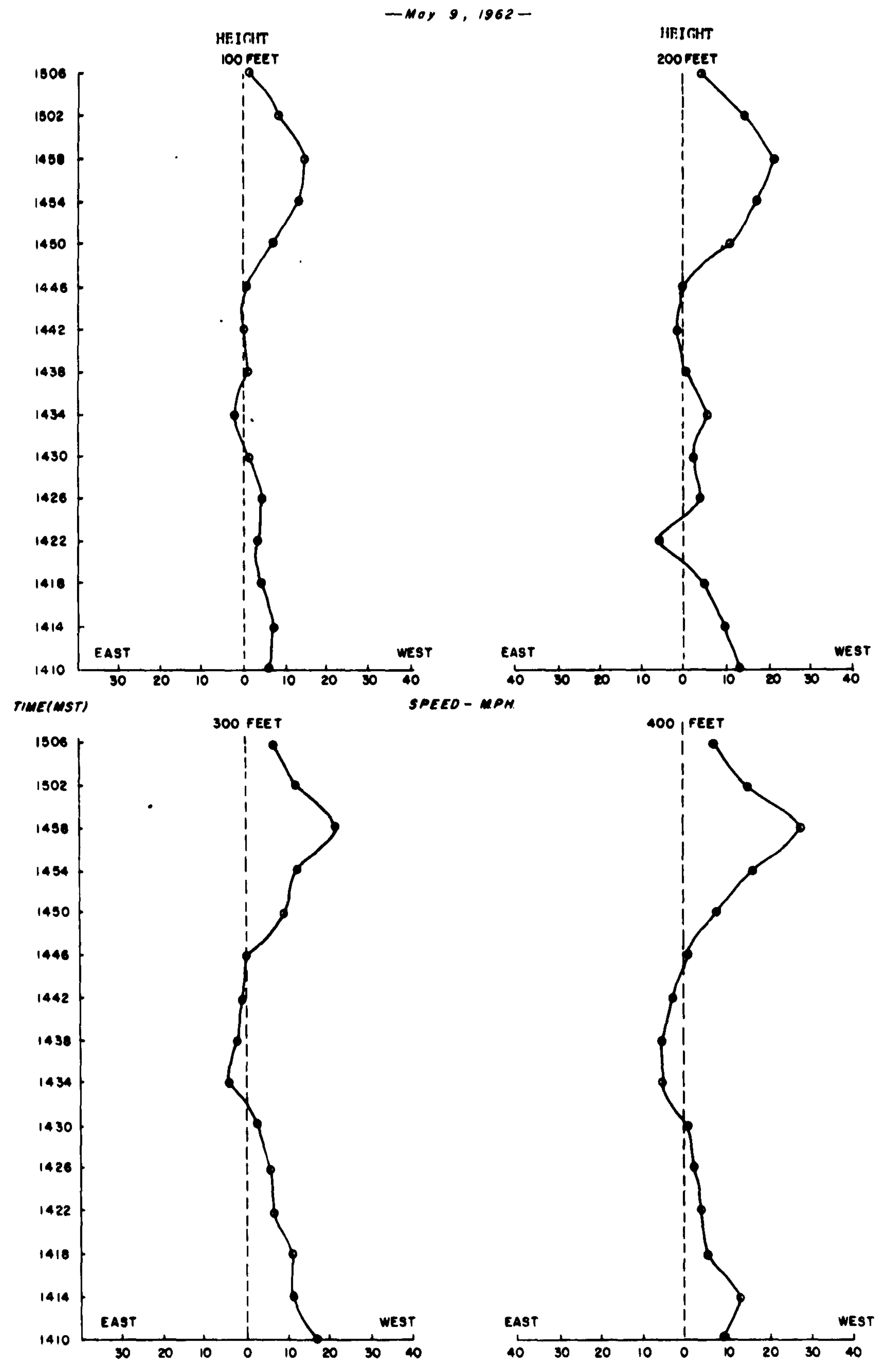
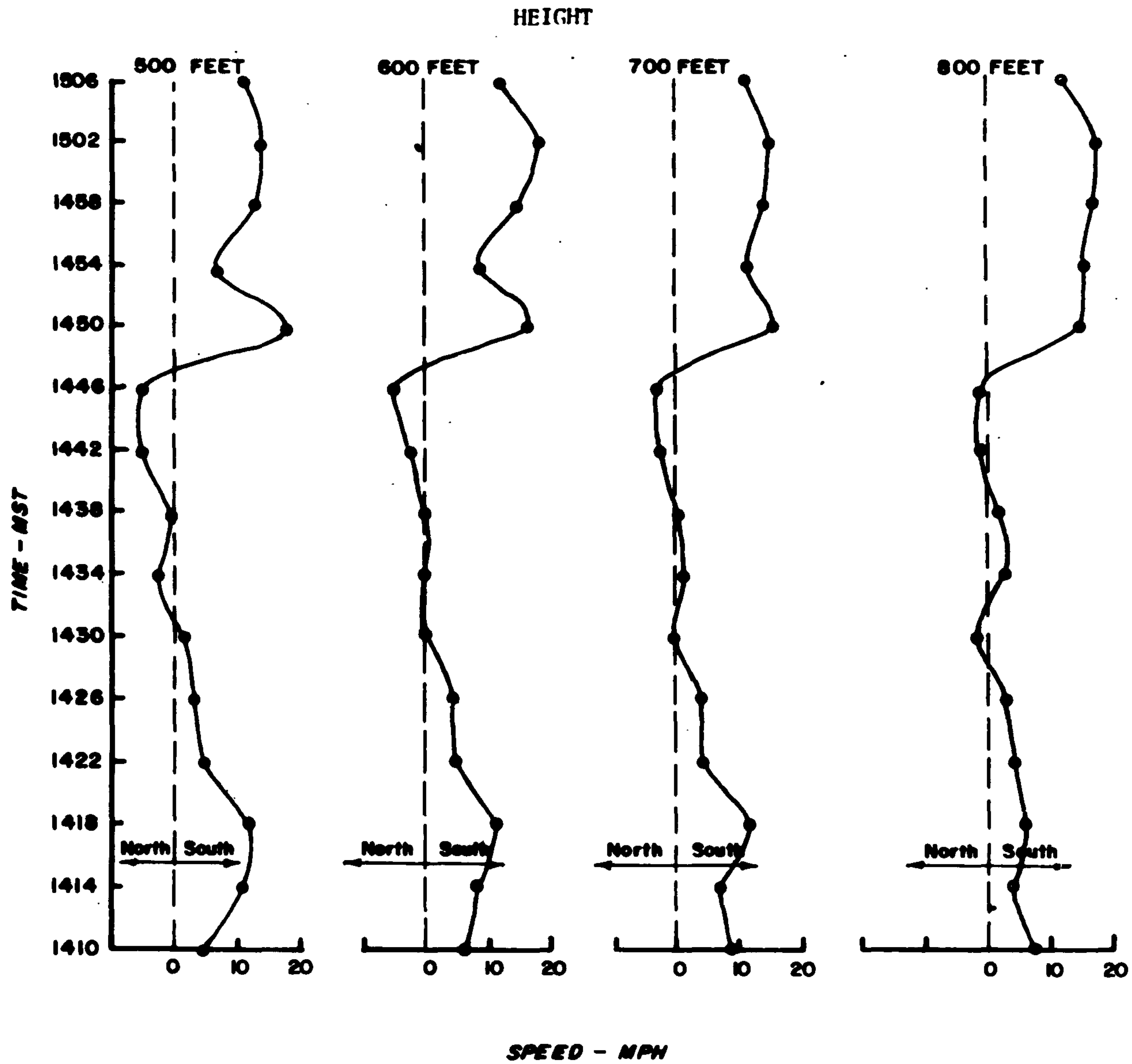


Figure 5. E-W Wind Components Per Unit Time (100-400 Feet).



N-S Wind Components Per
Unit Time (500-800 Feet)

FIGURE 6

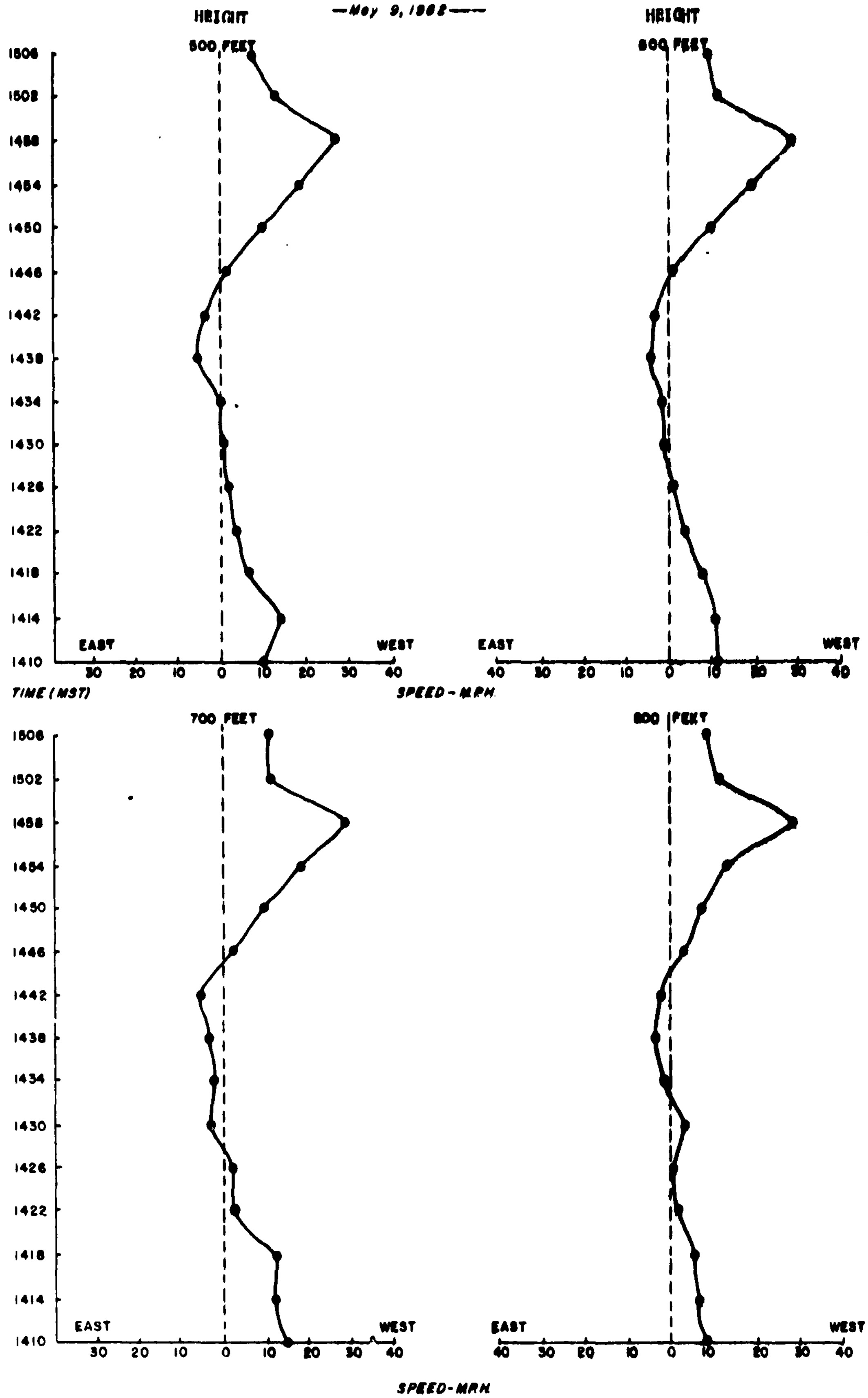


Figure 7. E-W Wind Components Per Unit Time (500-800 Feet).

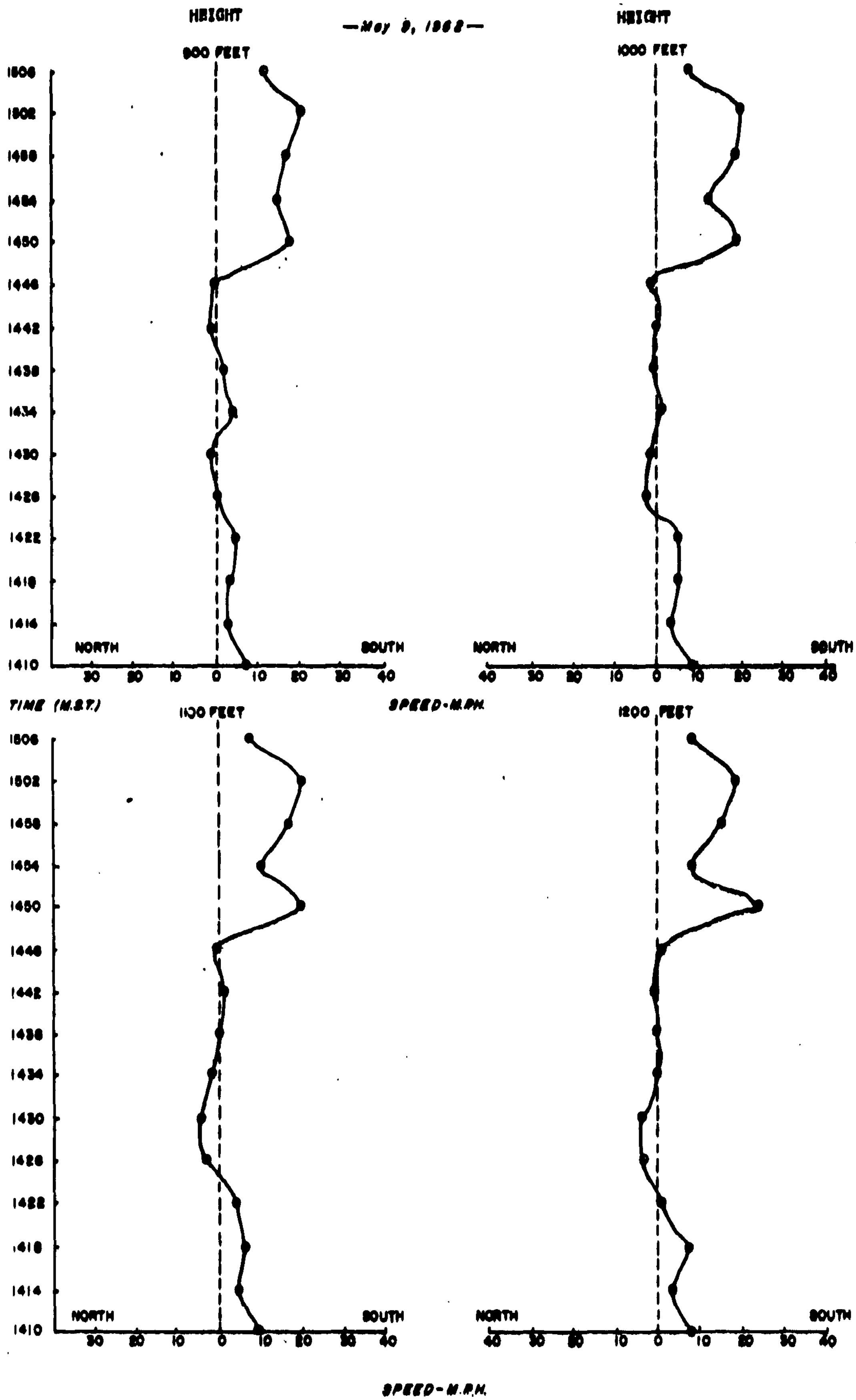


Figure 8. N-S Wind Components Per Unit Time (900-1200 Feet).

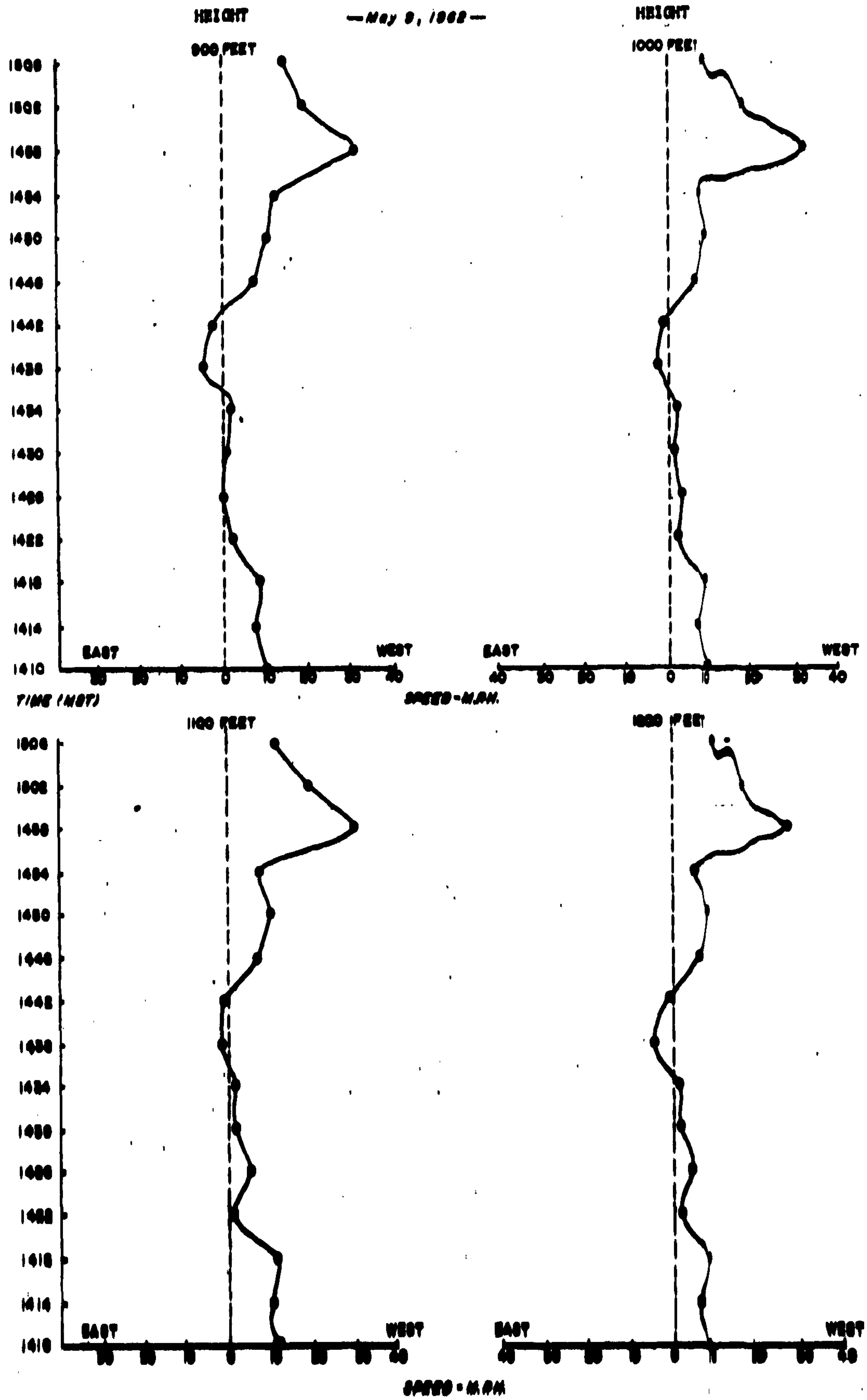


Figure 9. E-W Wind Components Per Unit Time (900-1200 Feet).

TABLE XIII

Change in Missile Impact Point (Displacement) in a Four-Minute Interval for Aerobee-Hi. Unit Wind Effect of 4.3 Miles Per Ballistic Mile Per Hour.

Time - 1446 MST

Height of Layer Feet	Components (MPH) N-S	E-W		Ballistic Wind N-S	E-W
143-200	3.0N	0W		.33N	.0 W
200-300	1.0N	0W		.10N	.0 W
300-400	0N	0.5W		.0 N	.03W
400-600	4.5N	0.5W		.38N	.04W
600-800	3.0N	1.5W		.50N	.26W
800-1000	1.0N	5.0W		.06N	.31W
1000-1200	0N	5.5W		.0 N	.09W
1200-1400	1.5S	5.5W		.02S	.07W
1400-1600	1.5S	8.0W		.02S	.10W
1600-1800	2.0N	11.5W		.02N	.14W
1800-2000	3.0N	12.0W		.03N	.12W
			Total	1.38N	1.15W
			Displacement	5.9N	4.9W

Time - 1450 MST

143-200	15.0S	10.0W		1.35S	0.90W
200-300	16.5S	9.0W		1.70S	0.93W
300-400	13.0S	7.0W		0.70S	0.38W
400-600	17.0S	9.0W		1.43S	0.76W
600-800	15.0S	9.0W		2.52S	1.51W
800-1000	17.0S	10.0W		1.05S	0.62W
1000-1200	20.5S	9.5W		0.35S	0.16W
1200-1400	23.0S	9.0W		0.28S	0.11W
1400-1600	26.0S	15.0W		0.31S	0.18W
1600-1800	20.0S	17.5W		0.24S	0.21W
1800-2000	19.0S	17.5W		0.19S	0.18W
			Total	10.1S	5.9W
			Displacement	43.6S	25.5W

CONCLUSIONS

Wind variations, as characterized by the dispersion of wind speed and direction about the mean, can cause significant differences in the computed impact of a rocket. This dispersion approximates the dispersion circle of 15-mile radius of predicted impact as computed for the Aerobee rocket at White Sands Missile Range. However, some of the error in predicted impact can also be attributed to the difference in the dynamic characteristics of the rockets since it is unlikely that any two rockets (even though apparently similar) fired under the same atmospheric conditions would impact at the same point.

The data presented indicate that the magnitude of the dispersion of the computed impact point of an Aerobee rocket caused by wind variation is within approximately a 15-mile radius. If extreme turbulent conditions prevail, wind variation can account for a much larger dispersion. Also, as rockets are improved to attain greater altitudes (in excess of 150 miles) the dispersion circle can be magnified depending on the ballistics of the rocket.

The information on wind-induced dispersion can be used by the meteorologist or ballistician to determine the probability of impacting the rocket in a desired or safe area. It can also be applied in determining the probability for success of some rocket experiments.

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NOTICES

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HEADQUARTERS
U. S. ARMY ELECTRONICS RESEARCH AND DEVELOPMENT ACTIVITY
WHITE SANDS MISSILE RANGE
NEW MEXICO

January 1963

1. Technical Report SELWS-M-21 has been prepared under the supervision of the Missile Meteorology Division and is published for the information and guidance of all concerned.

2. Suggestions or criticisms relative to the form, contents, purpose, or use of this publication should be referred to the Commanding Officer, U. S. Army Electronics Research and Development Activity, ATTN: SELWS-M, White Sands Missile Range, New Mexico.

FOR THE COMMANDER:

L. W. ALBRO
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